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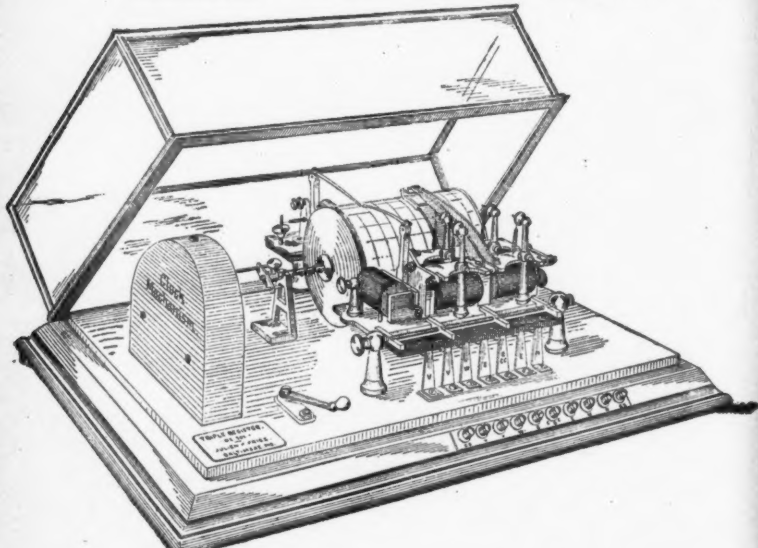

THE AMERICAN

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THE CLIMATE OF THE EASTERN PORTION OF THE COAST DISTRICT OF TEXAS IN ITS RELATION TO THE CULTIVATION OF FRUITS AND VEGETABLES. (YEARS 1873 TO 1892 INCLUSIVE.)*

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FRUIT and vegetables promise to become the leading products over portions of Texas, especially the eastern portion of that section known as the coast district. In view of this it is believed that the compilation and discussion of the rainfall for each month, the minimum temperature for the winter months, or months in which the temperature might probably sink low enough to slightly injure fruit or vegetables, and the maximum temperature for the summer months, compiled from all available sources, will be of interest and value. The records of Galveston, New Ulm, Houston, Brazoria, Columbia, and Orange have been considered in the discussion of this subject. In this discussion, where the average maximum or highest temperature is referred to, the average of the highest monthly for the various stations in the district has been used. Where the average lowest or minimum temperature is referred to, the average of the lowest monthly for the various stations has been taken.

The average precipitation in 1873 for this section was 71.99 inches, which is 20.45 inches above the normal. The amount was well distributed throughout the year. The least monthly was 1.32 in. in February, and this ranged from .50 in. along the immediate coast to 2.15 in. within the limits of the 100-foot contour line of elevation. The greatest monthly for the district

* By permission of the Chief of the Weather Bureau.

was 11.92 in. in November. The average of the lowest temperatures during this year was 19° above zero in January, and it ranged from 21° along the immediate coast to 16° or 17° 100 miles inland. The average maximum temperature for the district in 1873 was 98° in July; it was 95° along the immediate coast and was slightly above 98° 100 miles inland. During May and September the temperature along the immediate coast did not reach a maximum of 90°; in June it was 90°, while about 100 miles from the coast it was from 5° to 8° higher during these months.

The precipitation was not as well distributed in 1874 as in 1873; the greatest monthly was in September, when it ranged from 5.84 in. along the immediate coast to a little over 15.00 in. inland. During October there was only .12 in. along the coast, while 50 or 60 miles away the precipitation was about 1.00 in. The lowest temperature in 1874 occurred in January, when it was slightly above freezing along the coast, while only a short way from the coast it was at about the freezing point. The maximum temperature along the immediate coast in 1874 was 98° in August, which was the highest temperature recorded in August along the coast during the 20 years under discussion; it reached 87° in May, 93° in June, 96° in July, and 91 in September; it was slightly higher during these months 100 miles from the Gulf.

In 1875 the precipitation was well distributed during the year except in September, when there was over 18 in. along the immediate coast, and about 12.00 in. inland; and in August it was 6.15 in. along the coast and less than 1.00 in. only a short distance away. The lowest temperature in 1875 occurred in January, when the minimum ranged from 20° to 24°. The temperature fell to about freezing at New Ulm in February and March, but did not go below 35° near the coast. The maximum temperature for the district in 1875 averaged 99° in July, and nearly as high in June and August. The maximum temperature along the immediate coast was slightly above 90° in May; it was 97° in June and July; 96° in August, and 94° in September; it was slightly higher during these months 100 miles from the coast.

In 1876 the precipitation was well distributed. The least monthly was 1.57 in. in October. The lowest temperature in 1876 did not go as low as freezing along the coast except in

December, when it was 6° below. It lacked 3° of falling to freezing in February and 4° in March. The highest temperature recorded along the edge of the Gulf during this year was 96° in July; it was 89° in May, and 94° in June, August, and September; it was from 3° to 7° higher 100 miles from the coast during these months. The average highest temperature for the district was 99° in July.

The precipitation was very well distributed in 1877 except in September, when it was less than 2.50 in. inland, and was slightly over 13.50 in. near the coast; and in August it was less than .50 in. near the coast, while a short distance away it was slightly over 1.00 in. In October there was an excess of over 10.00 in. In this year the temperature fell slightly below freezing along the immediate coast in January and November, while inland it was 6° or 8° colder than near the coast. The maximum temperature in 1877 for the different stations in the district averaged 99° in July, and nearly as high in August; it was 91° along the immediate coast in May; 92° in June; 96° in July; 97° in August, and 93° in September; it was slightly higher 100 miles from the coast during these months.

The rainfall was very well distributed in 1878 The greatest monthly was 7.98 in. in August, and the least 1.69 in. in March. The minimum temperature did not go very low in 1878; the average lowest was 5° below freezing in December, and about freezing in January. The maximum temperature in 1878 along the immediate coast was 95° in July; it was 89° in May; 93° in June; 94° in August, and 89° in September; and it was from 3° to 6° higher 100 miles from the coast during these months. The average highest temperature for the district was 98° in July.

In 1879 the rainfall was considerably below the normal, but was well distributed except in October, when the amount was 3.00 in. greater inland than near the coast. The average minimum temperature in 1879 was 10° below freezing in January, and nearly as low in December. The maximum temperature along the immediate coast during this year was 89° in May; 94° in June; 92° in July; 91° in August, and 90° in September; it was a little higher 100 miles from the Gulf during these months. The average highest temperature for the various stations in the district was 96° in June.

In 1880 the precipitation was above the normal and evenly distributed over the district except in January and September, when it was irregular. In 1880 the minimum temperature was below freezing in November and December over all sections, and was about freezing in March 100 miles from the coast; while near the Gulf it was about 5° above freezing. The maximum temperature in 1880 for the several stations in the district averaged 98° in August; it was 93° along the Gulf coast, and about 100° 50 miles inland. It was 90° near the coast in May; 91° in June and September; 92° in July, and 93° in August; it was higher during these months 100 miles inland.

The rainfall in 1881 was very well distributed, except in January, March, May, June, and September, when it was below the normal, the greatest deficiency being about 4.00 in. in June. The minimum temperature for the various stations in the district during this year averaged about 6° below freezing in January, and slightly below in February. The maximum temperature along the immediate coast in 1881 was 89° in May; 94° in June; 92° in July; 93° in August, and 91° in September; it was from 3° to 9° higher during these months 100 miles from the Gulf. The average maximum temperature for the district was 98° in August, and nearly as high in June and July.

The rainfall in 1882 was about the average, or slightly above, except in March, April, and June, when there was a slight deficiency. The average minimum temperature in 1882 was 32° in December, and it did not average as low as 35° during any of the other winter months. The average highest temperature for the district in 1882 was 94° in August; it was 90° along the immediate coast, and about 8° higher 100 miles inland. The maximum temperature along the coast was 87° in May and September; 92° in June; 91° in July, and 90° in August; it was from 3° to 8° higher during these months 100 miles inland.

The precipitation was very well distributed in 1883, and was about the normal, except in August, when there was a deficiency of 2.66 in., and in March, when there was an excess of 5.09 in. The average rainfall of the various stations in the district during the year was about 1.61 in. above the normal along the immediate coast, while it was about 8.00 in. above the average 100

miles inland. The minimum temperature in 1883 was about 12° below freezing along the immediate coast in January, and slightly below in February; while it was colder 100 miles inland. The lowest average minimum temperature for the district was 18° in January. The highest temperature during this year averaged for the district 96° in July and August; it was 1° colder along the immediate coast in July than in August, while 100 miles from the coast it was slightly the coldest in August. The maximum temperature along the immediate coast was 85° in May; 91° in June, and 90° in September; it was slightly higher 100 miles from the coast during these months.

During the year 1884, the precipitation was fairly distributed except in July and August. In July only about 1.00 in. fell along the immediate coast, while inland there was no precipitation during the month. In August there was a deficiency of 2.89 in. The coldest weather in 1884 occurred in January, when the minimum temperature for the various stations in the district averaged 17°; it was about 10° below freezing along the immediate coast, while 100 miles inland it was 10° colder than near the coast. The highest temperature for the various stations in the district in 1884 averaged 98° in July; it was 95° along the immediate coast, and 100° in the vicinity of New Ulm. The highest temperature along the edge of the coast was 84° in May; 91° in June; 93° in August, and 90° degrees in September, and was 3° to 7° higher during these months at a distance of 75 or 100 miles from the Gulf.

The precipitation in 1885 was about normal during each month except in September, when there was an excess of about 4.00 in. During this month there was about 26.00 in. along the immediate coast, while inland the precipitation ranged from 4.00 to 9.00 in. During the year 1885, the minimum temperature went down to about 11° below freezing along the immediate coast in January; 4° below in March, and was within 2° of freezing in December, while away from the coast it was from 6° to 8° colder in the first named months, and went down below freezing in December. The lowest average of the minimum temperatures for the various stations in the district was 21° in January. The average maximum temperature during this year was 97° in July. During this month the maximum temperature along the immediate coast was 94°, while 60 miles inland it was nearly 100°.

It was 88° in May near the coast; 92° in June and August, and 91° in September, while at a distance of about 100 miles from the Gulf it was from 4° to 8° higher.

In 1886 there was a general deficiency in precipitation, except in March and September, when it was above the average, there being an excess in September of 5.77 in. The coldest weather which has occurred was in January, 1886, when the minimum temperature went down to 11° above zero at Galveston, and to 7° inland. The maximum temperature in 1886 in the vicinity of New Ulm was 104° in July and August, and 90° in June, while along the immediate coast it was 92° in July, 94° in August, and 90° in June. It was 87° near the Gulf in May, while 100 miles inland it was 10° higher. The temperature along the Gulf coast did not reach a maximum of 90° in September, while 100 miles from the coast it was 94°. The average highest temperature for the district was 99° in August, and nearly as high in July.

In 1887 there was a general deficiency in precipitation, except in June, July, August, and December, when it was slightly above the normal. The greatest deficiency was 4.69 in. in January. The average minimum temperature in 1887 was below freezing in January, November, and December; it was only a few degrees below along the immediate coast, while inland it was about 7° below freezing. The average lowest temperature for the district was 20° in January. During the year 1887, the maximum temperature was 100° in the vicinity of New Ulm in August, while it was 9° lower near the Gulf. The highest temperature along the immediate coast during the year was 93° in July, while it was 5° higher 100 miles inland. The temperature did not reach a maximum of 90° along the coast during May, June, and September, while it ranged from 95° to 98° 100 miles from the Gulf. The average highest temperature for the various stations in the district was 96° in July and August.

During the year 1888, the precipitation was very well distributed except in March, April, and July, when it was slightly below the average, and in January there was a deficiency of 3.11 in. The greatest monthly excess was 5.16 in. in June; the annual rainfall was 8.06 in. above the normal. The minimum temperature in 1888 was slightly below freezing in January, along the immediate coast, and was 11° colder in the vicinity of

New Ulm than it was along the Gulf. The average lowest temperature for the district was 18° in January. The highest temperature at the various stations during this year averaged 96° in August; it was 94° along the immediate coast, and was about 98° 100 miles inland. The maximum temperature along the edge of the coast was 86° in May; 90° in June; 91° in July, and 87° in September. It ranged from about 3° to 6° higher for these months at a distance of 100 miles from the coast.

The precipitation in 1889 was below the normal except in January, June, and November, when it was above; the greatest excess was 2.41 in. in January, and the greatest deficiency was 3.38 in. in October. The precipitation was very well distributed. The least monthly and poorest distribution of rainfall was in October, there being comparatively no precipitation along the immediate coast, while 100 miles from the Gulf it was slightly over .50 in. The minimum temperature in 1889, over a territory extending out 50 miles from the edge of the coast, was down to freezing in January and slightly below in November, while 100 miles from the coast it was 2° below freezing in January, 5° below in March, and 1° below in November. The average of the minimum temperatures of the various stations in the district was 30° in January. The average maximum temperature for the district in 1889 was 95° in July; it was about 97° 100 miles from the coast, and 90° along the immediate coast. The maximum temperature along the edge of the coast was 88° in May and September, and was from 2° to 4° higher 100 miles inland during these months. In June it was 86° along the immediate coast, which is the lowest maximum temperature recorded along the Gulf coast in this month during the twenty years under discussion. It was about 7° higher a short distance inland.

The rainfall in 1890 was as a rule well distributed. The greatest monthly deficiency was 2.96 in. in November, and the greatest excess was 3.37 in. in April. The lowest temperature that occurred during this year was 21° above zero, which occurred in Austin and Colorado counties during March; while along the coast it lacked from 2° to 5° of going down to freezing during January, February, and December, and in March it sunk 2° below freezing, which is the lowest temperature that has occurred along the immediate coast during March in the twenty

years under discussion, and about the only time that the temperature during the month of March went down low enough along the coast to prove destructive to tender vegetation. During the year 1890 the maximum temperature was 101° in the vicinity of New Ulm in July, and 100° in August, while along the immediate coast it was 92° in July and 90° in August, which makes a difference in temperature over the district of 9° in July and 10° in August. The maximum temperature along the edge of the coast was 85° in May and 87° in September ; it was from 6° to 10° higher a short distance away from the coast during these months. The average maximum temperature for the district was 97° in July, and about as high in June.

In 1891 there was a general deficiency in precipitation ranging from .07 in. to 3.64 in., except in January, July, and December, when there was an excess, the greatest being 2.59 in. in December. There was an annual deficiency in precipitation during the year amounting to 10.54 in. During the year 1891, the minimum temperature lacked 2° of going down to freezing along the immediate coast, while one hundred miles inland it went down to about 5° below freezing in January ; 5° to 6° below in February ; 2° to 4° below in March, and about 7° or 8° below freezing in December. The average highest temperature for the district was 28° in December. The average highest temperature for the various stations during this year was 96° in July ; it was 92° along the Gulf coast, and about 98° in the limits of the 100-foot contour line of elevation. The maximum temperature along the immediate coast was about 86° in May and September, and was 90° in June and August ; it was from 6° to 10° higher a short distance inland during these months.

The precipitation in 1892 was slightly above the normal in July, August, and November, while during the other months there was a general deficiency, the greatest being 5.16 in. in September. There was a deficiency of rainfall, during the year, of 21.25 in., being the greatest annual deficiency over this portion of the State during the twenty years under discussion. The minimum temperature in 1892 went down about 7° below freezing along the immediate coast during January and December, while 100 miles inland it was 12° below freezing in January, and about 13° in December. The average lowest temperature for the district was 21° in December. The highest temperature in

May, 1892, averaged, for the various stations in the district, 88°; it was 84° along the immediate coast, while only a short distance inland it was 90°. The highest temperature for the various stations in the district averaged 95° in June, and nearly as high in August. The maximum temperature was 88° along the immediate coast in July and September, while about 100 miles from the coast it was 96° in July, and 92° in September.

The following table shows the monthly rainfall in inches for twenty years over the district under discussion:—

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1873	4.72	1.32	3.80	5.14	3.62	9.97	10.60	6.26	8.16	3.68	11.92	2.80	71.99
1874	1.80	5.02	5.77	3.84	4.53	2.72	7.88	4.58	10.46	.46	3.70	7.94	58.52
1875	4.00	4.97	3.04	3.80	2.86	1.39	1.62	3.52	15.45	2.66	4.56	13.07	60.94
1876	2.46	3.62	6.54	1.86	8.20	2.93	5.68	6.40	2.08	1.57	2.56	3.17	47.07
1877	2.83	3.94	2.80	7.15	3.15	5.84	2.00	.91	8.12	14.35	6.40	5.60	63.09
1878	4.77	3.72	1.69	2.69	3.73	3.92	6.57	7.98	5.07	2.46	7.14	7.04	56.78
1879	3.13	1.24	2.44	4.50	2.55	2.51	2.54	5.68	2.46	2.30	1.36	2.33	33.04
1880	3.55	4.64	7.84	2.92	5.16	6.46	5.62	2.84	7.22	2.85	8.74	1.30	59.14
1881	2.84	8.30	1.96	3.76	4.06	.33	5.30	5.80	3.54	11.41	5.80	3.53	56.63
1882	9.36	8.26	3.20	1.49	7.35	2.98	3.89	6.62	3.83	6.10	4.92	3.02	61.02
1883	7.09	2.73	9.03	3.67	9.42	3.91	1.60	1.22	6.13	4.50	5.10	2.76	57.16
1884	4.27	1.74	4.85	4.97	10.88	6.48	.77	.99	6.74	4.81	4.65	6.53	57.68
1885	5.50	1.55	2.66	4.92	6.04	1.70	2.84	1.37	10.81	1.74	1.60	2.94	43.71
1886	2.29	1.98	3.97	2.48	.03	3.51	1.62	3.62	12.45	.88	2.08	.77	35.68
1887	1.14	1.93	1.62	.09	3.60	5.35	3.62	5.16	4.21	3.16	.26	7.62	37.76
1888	2.72	6.10	2.78	2.81	8.20	10.43	2.53	7.58	2.38	4.27	6.04	3.76	59.60
1889	8.24	2.46	3.27	1.97	2.98	7.20	2.04	3.31	5.74	.18	4.27	.26	42.10
1890	5.11	3.52	3.72	6.98	5.55	6.32	2.02	4.68	6.14	5.20	2.76	1.26	53.26
1891	7.50	3.41	1.90	2.56	1.74	2.89	4.84	2.38	5.00	.66	3.03	5.09	41.00
1892	1.65	1.66	1.66	1.33	.48	3.97	3.21	5.04	1.07	3.34	4.68	2.20	30.29

The following table shows the average of the monthly minimum temperatures, in degrees, of the various stations in the district under discussion for the past twenty years: —

	January.	February.	March.	April.	October.	November.	December.
1873....	19	41	42	42	44	40	38
1874....	32	41	50	46	48	40	37
1875....	22	32	32	46	54	45	38
1876....	40	32	34	52	49	37	24
1877....	28	44	37	52	47	28	33
1878....	32	36	50	51	48	53	27
1879....	21	37	42	54	49	41	22
1880....	45	38	35	44	50	27	16
1881 ...	26	30	44	45	57	35	41
1882....	36	44	42	51	57	37	32
1883....	18	28	40	57	52	41	39
1884....	17	25	37	44	54	37	27
1885....	21	26	39	60	56	44	30
1886....	9	28	36	40	46	31	22
1887....	20	37	44	47	46	32	28
1888....	18	41	38	52	50	36	35
1889....	30	34	44	55	44	32	42
1890....	30	28	27	46	48	38	29
1891....	29	29	32	40	46	31	28
1892....	22	45	28	50	44	35	21

The following table shows the highest monthly temperatures averaged from the several stations in the district under discussion for the past twenty years: —

	May.	June.	July.	August.	September.
1873.................	90	92	98	95	91
1874.................	91	95	98	99	92
1875.................	94	98	99	98	95
1876.................	91	96	99	95	94
1877.................	92	94	99	98	95
1878.................	90	94	98	95	90
1879.................	92	96	95	94	92
1880.................	91	94	95	98	93
1881.................	92	97	97	98	94
1882.................	88	90	92	94	91
1883.................	86	92	96	96	91
1884.................	86	93	98	94	92
1885.................	90	94	97	95	93
1886.................	92	96	98	99	92
1887.................	91	92	96	96	94
1888.................	88	92	92	96	90
1889.................	90	91	95	94	90
1890.................	92	96	97	95	92
1891.................	89	95	96	95	92
1892.................	88	95	93	95	90

We find from these records that the greatest monthly precipitation over this district, during the twenty years under discussion, was 14.35 in. in October, 1877, that being 10.79 in. above the normal for this month; while the least precipitation was .03 in. in May, 1886, that being 5.37 in. below the average. On an average the rainfall over this district is greatest in September, and least along the coast generally in February, while 100 miles from the coast the least is generally in August. The greatest annual precipitation for the district was 71.99 in. in 1873, which is 20.45 in. above the average. The least annual rainfall was 30.29 in. in 1892, which was 21.25 in. below the normal.

January is the coldest month in the year and gives the lowest temperature. The records show that the minimum temperature for the twenty years has fallen, in some parts of the district under discussion, below 20° in 5 years, below 25° in 10 years, and below 30° in 13 years; and along the immediate coast during the years 1874, 1882, and 1891 it did not reach a minimum of 33°. The average highest temperature for the district during the twenty years under discussion was 99° in August, 1874, in July, 1875, 1876, and 1877, and in August, 1886; the lowest was 86° in May, 1883 and 1884. We find from the observations that the temperature along the immediate coast has not reached a maximum of 100° during the twenty years, and that the highest recorded was 98° in August, 1874. The maximum temperature near the coast during the past fifteen years was 95° in July, 1878, August, 1883, and July, 1884; and the highest during the past 5 years was 94° in August, 1888. We find from examining the records that the temperature generally ranges from 3° to 12° higher 100 miles inland than near the coast.

July is found to be slightly the warmest month for this district and generally gives the highest temperature. The highest along the Gulf during the above month in the twenty years was 97° in 1875; and the highest in the past ten years was 95° in 1884.

The extreme southern portion of this district is subject nearly every winter to light frosts. Killing frosts do not usually occur over the territory between the edge of the Gulf and the 100-foot contour line of elevation until after Dec. 1; and along the immediate coast it is frequently delayed until

January. During the twenty years under discussion there have been 4 years without frost, and 5 with a single frost at Galveston. Only one killing frost occurred along the immediate coast, previous to Dec. 1, during the twenty years, and that one occurred on Nov. 18, 1880. The average date of first killing frost sixty miles from the coast is Dec. 15, while along the immediate coast it is Dec. 25. The average date of last killing frost in spring along the edge of the coast is Jan. 5, while fifty miles inland it is Feb. 1.

During the past few years fruit and vegetables have been cultivated very extensively over the eastern portion of the coast district, and it has been proved that apricots, peaches, pears, oranges, strawberries, dates, limes, bananas, figs, grapes, Japanese persimmons, almonds, pomegranates, pecans, quinces, and blackberries can be grown, and some of them with marked success. The cultivation of strawberries is being carried on very extensively over the eastern portions of the coast district. The berries raised are of the finest grade and are very large. With few exceptions the berries grown in this portion of the State are ready for market by the last of February, which is generally from one to two weeks earlier than they can be marketed from any other sections of the country. The banana has not been cultivated very extensively over this section for the reason that it is only a few years since it has been raised successfully. Where suckers have been planted they prove to do well, and the fruit raised from them is of a nice quality and appears to be equally as good a grade of fruit as that shipped here from Honduras, Bluefields, Jamaica, or other banana ports. The banana must be raised from suckers over this territory, as there is only one small spot on the earth where the banana will seed, and that place is the Andaman Islands; there it can be raised successfully from seeds. But over other portions of the earth the plant must be raised from suckers or else the trees will not produce fruit. The banana trees at different degrees of development renew themselves with offshoots, and each plantation at the same time offers rows whose branches are full of blossom, young offsets which give promise of future plenty, and rows whose branches are laden with ripe fruit. It is said that in the section best suited to bananas four rows and generally five are obtained two years after planting them out. Prof. F. M.

Boussingault, a prominent writer on tropical agriculture, says: "There is no culture than can be undertaken with more confidence than that of the banana, for if climatic influences should sometimes have a prejudicial effect on the crop, they could never completely destroy the prospects of a harvest, as the certainty would always remain of that to be obtained from the surviving and stronger-growing offshoots or suckers. No other vegetable production presents similar advantages — not even the maize, that crop so precious in the warmer regions of the globe."

Grapes are classified among the leading fruits for cultivation over this section of the State, and it is proved that the climate along the coast is better suited for the varieties of grapes known as the Delaware, Ives, Champion, Niagara, and Concord. Other varieties can be raised but they are more liable to be injured by the ordinary vine diseases. The European varieties of grapes put forth their fruit too early in this climate and are subject to mildew and give little promise of success. The much dreaded black rot, which proves very destructive among some vineyards over other sections of country, is little known among the grapes cultivated over the coast district of Texas. This disease has never injured grapes to any extent over this portion of the State. But sometimes grapes are injured over this district by what is known as the bitter or ripe rot, especially if there is much rainfall during July, the month that grapes are ready for picking. This disease, after it gets started, continues to develop on the fruit after it is picked until it is consumed or preserved. Forunately for this valuable product, July is one of the months with light rainfall which tends to make the climate favorable.

The pear is a sure crop over this district and is of unusually large size and of fine flavor. The olive thrives as far north as the thirty-second parallel, and it is believed that, in the course of a few years, the cultivation of the olive will be one among the leading industries carried on over portions of this district.

It is believed in the course of time that every acre of land over this territory will be under cultivation, and it will be one of the leading fruit-growing sections in the country. Besides the advantages of the cultivation of different tropical fruits over

this district it is stated in Appendix No. 7, United States Senate Executive Document No. 5, 52d Congress, 1st Session, that "The gulf coast of Texas offers unsurpassed advantages as a winter health resort. The orange, banana, date, and other tropical fruits thrive in this section, and with the exception of an occasional season with moderately low temperature, flowers bloom out doors in every month of the year. Excessive changes in temperature are rare, and the northers of northwest Texas never amount to more than a cool wave along the coast. The temperature ranges generally from 35° to 60°, with pleasant, prevailing fresh to brisk southerly winds from the Gulf, which give an equable climate where outdoor exercise and sports can be engaged in throughout the winter without the least inconvenience. The above, with other unexcelled natural facilities, such as boating, fishing, and hunting, furnish advantages for recreation which cannot be appreciated until experienced; and they are of that character most desired by the pleasure and health seeker. The statement of Robert Russell, in his 'Climate of America,' that the temperature has been known to fall, in Southern Texas with a norther, from 81° to 18° in forty-one hours, has not been verified here during the twenty years the record has been kept, and such changes have never been known to have occurred except in Northern Texas, a distance of 400 miles from the coast. January is generally the coldest month in the year, and gives the lowest temperatures. The record at Galveston for this month, for twenty years, shows that the minimum temperature has been below 30° in eleven years and below 20° in one year only. From fifteen years' record it is found that the temperature during December, January, and February falls 10° or more in twenty-four hours on an average of 8 days in 100, and rises 10° or more on 6 days in 100; and while the changes are probably slightly greater than the above for the entire coast region, yet they cannot exceed this to any great extent. A fair idea as to the health of this section may also be taken from Galveston as a base. The average annual death rate at Galveston is about fifteen per thousand inhabitants. Pulmonary consumption leads with one in every fourteen deaths, which is one third less than the average mortality from this dread scourge for the world. Pneumonia comes second, with an average of one in every twenty-

eight deaths. Following these are a few diseases which give a death rate of one in fifty, or slightly greater, and the remainder give one or less in one hundred deaths. No epidemic diseases have visited this section since 1870, nearly a quarter of a century, except a few cases of smallpox, from which only seven deaths have occurred during the past seventeen years. Periodical fevers are not observed to any extent worthy of notice in this section, and, in fact, are almost entirely absent. Epidemic diseases are kept away by strict and systematic quarantine, which is carried on at the proper season without any material injury to commerce. It is a fact deserving mention that the more destructive epidemic diseases have never been known to have had their first origin here, and when transplanted to this section have not been propagated to anything like the same extent they have under other semitropical climates."

THE MOVEMENTS OF THE AIR AT ALL HEIGHTS IN CYCLONES AND ANTI-CYCLONES, AS SHOWN BY THE CLOUD AND WIND RECORDS AT BLUE HILL.

H. HELM CLAYTON.

DURING the three years 1887 to 1889, frequent observations of the clouds were made at Blue Hill. For two of these years observations were made hourly for sixteen hours of each day. A record was made of the kind of each cloud visible, its direction of motion and relative velocity. The number of observations at which the directions of motion of the clouds were obtained was about eight thousand. A nephoscope devised by the writer was used for obtaining the cloud directions and relative velocities which were measured in such a manner that the absolute velocity of a cloud could be determined when its height was known. The mean cloud heights have since been determined at Blue Hill, and used to convert the mean relative velocities to absolute velocities.

In entering the observations, the clouds were separated into five levels. The highest level was called the cirrus level, the next the cirro-cumulus level, the next the alto-cumulus level. the next, the cumulus level, and the lowest, the stratus level, The average height of the clouds recorded under each of these

levels was found by direct measurements to be as follows: cirrus level, 8,884 metres; cirro-cumulus level, 6,633 metres; alto-cumulus level, 3,856 metres; cumulus level, 1,614 metres; stratus level, 508 metres. In order to obtain the movements of the clouds at these separate levels in different parts of cyclones and anti-cyclones the five degree squares formed by the intersection of the lines of latitude and longitude, as they are usually recorded on maps, were used. In all the cases in which Blue Hill was in a five degree square south of a cyclone, or anti-cyclone centre, the cloud observations for each level and the wind were taken from the records at Blue Hill and averaged; then all the cases in which Blue Hill was east of a cyclone or anti-cyclone centre were averaged, and so on for each five degree square around the centre, and out to a distance of six or seven hundred miles from the centre. The average direction in each square was obtained by means of Lambert's formula.

The mean relative velocity for each square was obtained and converted to absolute velocities by multiplying by a factor derived from a rational geometrical formula verified by direct measurements of cloud velocity.

The results thus obtained were plotted in the centres of the squares by means of arrows. The arrows were pointed in the direction toward which the clouds moved and the lengths of the arrows were made to show the velocity. In each diagram the mean velocity was represented by a length of ten millimetres, and the amount that each arrow exceeded or fell short of this limit shows how much the velocity at that point differed from the mean. A copy of these diagrams for the cirrus level of clouds and for the winds is given in Nos. 1, 2, 5, and 6, of the accompanying cuts.

The position of the centre of the cyclone, or anti-cyclone, is shown in each diagram by a small circle. Diagrams Nos. 1 and 2 show the movements of the air in the cirrus region; and Nos. 5 and 6, the circulation of the wind at the top of Blue Hill which is one hundred and twenty metres above the surrounding country and has a very free exposure. Nos. 1 and 5 show the circulation of the air at the top and bottom of cyclones, and Nos. 2 and 6, the circulation at the top and bottom of anti-cyclones.

Diagram No. 5, giving the wind circulation in the cyclone,

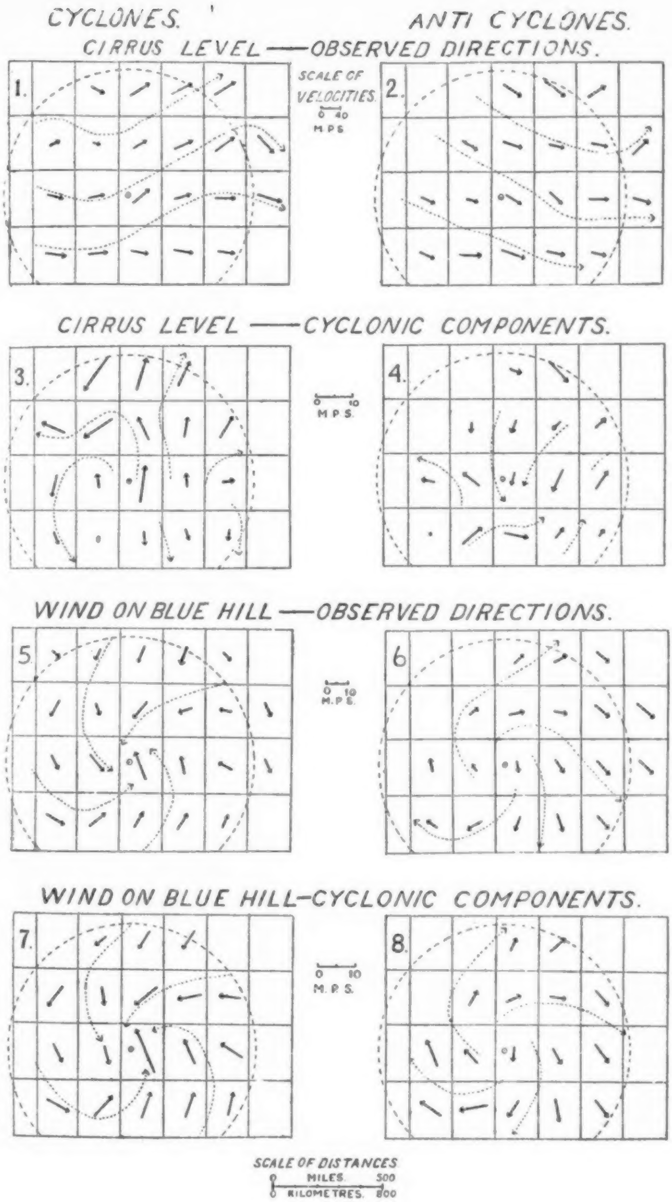
shows the well-defined spiral inward motion out to a distance of six hundred miles from the centre. Outside of this limit the wind appears to have the prevailing northwest direction found on Blue Hill. The outward spiral motion of the wind in the anti-cyclone is well shown in the diagram No. 6. The outer limit of this circulation is not so well defined as in the cyclone, but appears to be at about the same distance from the centre.

The increased velocity of the wind near the centre of the cyclone, and the decreased velocity near the centre of the anti-cyclone are distinctly shown by the lengths of the arrows. It is further apparent that the inclination of the wind to the centres of the two is not the same on all sides. In the cyclone, the winds blow most nearly tangential southeast of the centre, and most nearly inward, north or north-northeast of the centre; while in the anti-cyclone the winds are most tangential north-west of the centre, and most nearly outward south or southeast of the centre. This is most plausibly explained as due to the cyclonic and anti-cyclonic circulation struggling against a general atmospheric drift from the west-northwest. In the cumulus region the cyclonic and anti-cyclonic circulation is still visible; but the general westward drift has become much stronger and has partially overcome the circulation on the east side. Above the cumulus region, that is, above the height of about a mile, the cyclonic and anti-cyclonic circulation are entirely masked by the general westward drift, and their existence is only apparent by a deflection in the direction of the currents.* In the cyclones the currents are deflected to the right, and in the anti-cyclones to the left. This deflection will be understood by an examination of the accompanying diagrams (Nos. 1 and 2) of the currents in the cirrus level. The deflection is not so marked in this level, however, as in the two levels immediately beneath.

Above the cumulus level the highest velocities of the currents are found on the outer limits of the cyclone and anti-cyclone about six hundred miles northeast of their centres.

In the winds on Blue Hill the lowest velocities are found east of the cyclone centre; in the cumulus level the lowest velocities

* Diagrams showing the circulation of the air at each level of clouds will be published in the "Annals of Harvard College Observatory."


CYCLONES.
ANTI CYCLONES.
CIRRUS LEVEL — OBSERVED DIRECTIONS.
1.
2.
SCALE OF VELOCITIES.
0 40
M.P.S.
CIRRUS LEVEL — CYCLONIC COMPONENTS.
3.
4.
0 10
M.P.S.
WIND ON BLUE HILL — OBSERVED DIRECTIONS.
5.
6.
0 10
M.P.S.
WIND ON BLUE HILL — CYCLONIC COMPONENTS.
7.
8.
0 10
M.P.S.
SCALE OF DISTANCES
0 MILES 500
0 KILOMETRES 800

are found northeast of the cyclone centre ; in the cirro-cumulus and alto-cumulus levels, north of the centre ; and finally in the cirrus level, northwest of the centre ; thus showing a systematic displacement around the centre. The weakest current in each level is probably found where the cyclonic circulation most nearly opposes the general atmospheric drift at that height. The shifting of the position of lowest velocities is not so well marked in the anti-cyclone, probably because observations are wanting on the western limit.

Another thing shown by these diagrams is that the currents do not all turn to the right as one ascends into the atmosphere, as is usually stated. When the winds have a southerly component the upper currents come from a direction more and more to the right as one ascends, but when the winds have a northerly component the diagrams show that the currents turn to the left as one ascends.

An attempt was next made to separate the cyclonic and anti-cyclonic component of motion in each cloud level from the general eastward drift. To do this, it was assumed that the general atmospheric drift at each level of clouds was, in the average, uniform in direction and velocity, and could be found by obtaining the mean of all the directions and velocities in every part of the cyclone or anti-cyclone, provided the observations were equally distributed around the centre. On account of the position of the ocean, the observations were not equally distributed around the cyclone and anti-cyclone centres, there being more observations to the north and east than to the south and west. It was consequently necessary to correct for this inequality. This was done by obtaining separately the mean for each quadrant, — northeast, southeast, southwest, and northwest, — and giving the quadrants equal weight in obtaining the final mean. In doing this only those squares which lay within the area of the cyclonic circulation as shown by the wind arrows were used. The results are given in the accompanying table which gives the mean direction by Lambert's formula found in the cyclone and anti-cyclone separately and the mean of the two. The mean direction obtained from all the cloud observations, amounting to several thousand in each level, during the three years, 1887, 1888, and 1889, is also given. The means are given in degrees of azimuth counting from the south as zero, 90° being west.

The second part of the table gives the mean velocity for each level found by averaging all of the observed relative velocities in each square, and then by giving each square equal weight, obtaining a mean which multiplied by the proper factor gave the absolute velocities.

MEAN DIRECTION OF CURRENTS.						MEAN VELOCITY OF CURRENTS.				
Level.	Cyclone.	Anti-Cyclone.	Diff.	Mean of Two.	Mean, all Obs.	Level.	Cyclone.	Anti-Cyclone.	Mean of Two.	Mean from Mens.
	Az.	Az.	Az.	Az.	Az.		m.p.s.	m.p.s.	m.p.s.	m.p.s.
Cirrus.	87°	109°	22°	98°	97°	Cirrus.	35.5	38.5	3.70	38.5
Cirro-cumulus.	81°	96°	15°	89°	90°	Cirro-cumulus.	33.7	31.1	32.4	32.5
Alto-cumulus.	82°	88°	6°	85°	86°	Alto-cumulus.	19.3	20.1	19.7	15.7
Cumulus.	102°	130°?	?	116°?	90°	Cumulus.	11.1	10.8	11.0	11.3
Wind.	124°	124°	0°	124°	98°	Wind.	7.5	5.7	6.6	6.7

There are many interesting things to be found in these tables.

It is seen that the mean directions of drift in the upper levels of cyclones differ considerably from that in anti-cyclones, but the mean of the two at eaeh level agrees very well with the mean of all observations at that level. The difference between the cyclone and anti-cyclone is greatest in the highest level, and decreases as one approaches the earth where it disappears. The explanation of this is no doubt to be found in the temperature distribution around cyclones and anti-cyclones which has more to do with determining upper air gradients than has the sea level distribution of pressure.

The high temperature in front and low temperature in the rear of cyclones should, acccording to theory, produce a high pressure in the upper air in front of cyclones and a low pressure in the rear, thus tending to cause a southerly current over cyclones; while the reverse of these conditions should prevail in anti-cyclones and tend to cause a northerly current in the upper air over anti-cyclones. The deflection from the general westerly direction arising from these causes would be greatest in the highest levels and disappear at the earth's surface, which

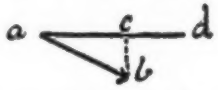
agrees remarkably well with the results of observation as shown in the above table. The fact that cyclones in their progressive movement generally take a course north of west and anti-cyclones a course south of west no doubt finds its explanation in the same source.

Another striking result shown by the tables is that the direction of the currents in the middle level of clouds is more southerly than in the levels above or below it, which in general move from a point north of west, while the middle levels move from a point south of west. This more southerly direction of the middle level is true for all parts of the cyclone and anti-cyclone, and is found in the mean of the observations under all conditions, so there can be no doubt of its existence.

The table shows that the mean drift of the winds in cyclones and anti-cyclones is more northerly than the mean obtained from hourly observations under all conditions. Thinking this might arise from the method of obtaining the mean, another method was tried. Only squares arranged systematically around the centre, that is, so that the same number were on each side of the centre, were taken, and each square given equal weight in obtaining a mean. The result gave a mean drift of the wind from one hundred and twenty-five degrees azimuth in both cyclone and anti-cyclone, which agrees almost exactly with the previous result found from the mean of the quadrants.

In the cumulus region the mean drift found in the anti-cyclone is considered doubtful because it is evident from the observations that local influences vitiated the result.

Having found the mean direction of drift in each cloud level, the next step was to separate this from the circulating component of motion in the cyclone and anti-cyclone. To do this it was first necessary to ascertain the mean velocity in the direction of mean drift in each cloud level. This was accomplished as follows: suppose in the following diagram the line *a b* to be



the average observed direction and velocity of the currents in any given square, then suppose *a d* to be the mean direction of drift as found above; it will be readily seen that the com-

ponent of velocity in the direction of mean drift is represented by *a c*. In other words, it is proportional to the cosine of the angle *b a c*, and hence *a c* can be obtained by multiplying *a b* by the cosine of this angle. This was done for each square, the minus sign being used to indicate an opposing direction. Using the squares equally distributed around the cyclone, or anti-cyclone centre, the mean excess of the positive over the negative velocities gave the mean velocity in the mean direction of drift. The above method was used instead of Lambert's formula, because the mean velocity in each square, represented by the lengths of the arrows in the diagrams, was not the mean by Lambert's formula, but the arithmetic mean of all observed velocities independent of the direction.

Having obtained the mean direction and velocity of drift, it was possible, by means of the parallelogram of forces, to obtain the cyclonic, or anti-cyclonic, component of motion in each cloud level.

The mean results obtained by these methods are given in the following table: —

	Cyclones.				Anti-Cyclones.			
Level.	Direction of Mean Drift.	Velocity in Direction of Drift.	Mean Cyclonic Component.	Mean Component Cor. for Density.	Direction of Mean Drift.	Velocity in Direction of Drift.	Mean Anti-Cyclonic Component.	Mean Component Cor. for Density.
	Az.	m. p. s.	m. p. s.	m. p. s.	Az.	m. p. s.	m. p. s.	m. p. s.
Cirrus.	87°	33.5	15.2	5.8	109°	37.5	13.0	5.0
Cirro-cumulus.	81°	30.7	14.6	6.9	96°	29.2	12.0	5.6
Alto-cumulus.	82°	16.2	8.3	5.6	88°	17.3	9.0	6.0
Cumulus.	102°	5.0	9.8	8.3	100°?	5.0?	9.3	7.9
Wind.	124°	1.2	6.9	6.9	124°	1.1	5.8	5.8

The mean velocity in the direction of mean drift, given in columns two and six of the above table, shows that the air drifts much more rapidly from the west in the higher regions than near the earth's surface. The means in columns three and seven, giving the mean cyclonic and anti-cyclonic components of motion, show that the air also circulates in cyclones and anti-cyclones more rapidly above than below. In this latter case the

increase of velocity appears to be approximately proportional to the decrease in density. If the atmospheric density in the lower air be taken as unity, the density at the mean height of each cloud level will be approximately as follows: cumulus, 0.85 alto-cumulus, 0.67; cirro-cumulus, 0.47; cirrus, 0.38. If the mean components are multiplied by these factors, the results given in columns four and eight of the table are obtained. These columns show that the velocity of circulation per unit mass is approximately the same at all heights, and varies between six and seven metres per second in cyclones; and five and six metres per second in anti-cyclones. This is what would be expected provided the same mass of air at each cloud level flows through the same vertical section. For instance, if in the cyclone, a given quantity of air flows in at the base and ascends to a height where the density is only a third as great as below, the air must flow out three times as fast as the inflow below, for the same mass to be removed, provided the inflow and outflow have the same vertical height, and this is what the above table indicates is approximately the case. This is also indicated by the diagrams of the different levels of clouds which shows that the inflow ceases in the middle level of clouds, and above that becomes an outflow. The mean cyclonic velocities for each square were multiplied by the above factors to reduce them to velocities per unit mass at each level and the results plotted. The results for the winds and for the cirrus level are given in the accompanying diagrams, Nos. 3, 4, 7, and 8.

These diagrams show very clearly the inward movement of the lower air, with the outward movement above; and the reverse for anti-cyclones. There is, however, a curious difference between the cyclones and anti-cyclones in the fact that the cyclones preserve in general the same direction of rotation above as below, while in the anti-cyclone the direction of rotation has become partially or entirely reversed. The writer interprets this to mean that in cyclones the air is carried out against the gradient by dynamic action; for if the outflow of air were due to a gradient, the air would be deflected by the earth's rotation, as Ferrel has clearly shown, and there would be an anti-cyclonic motion above.

The tendency to a right hand rotation above the anti-cyclone appears to prove that the inward flow is due to a gradient, and

the pressure is lower above the centre of the anti-cyclone than in the surrounding air. This latter fact furnishes evidence that the anti-cyclone is due in part, or entirely, to low temperature which causes an increase of density and pressure in the lower air, and a decrease above. The reversal of the gradient appears to take place in the cirro-cumulus region and probably reaches its maximum above the cirrus region.

In the cyclone there appears to be a tendency toward an anti-cyclonic circulation in the cirrus region southeast of the cyclone centre which interferes with the true cyclonic circulation on that side. This is no doubt due to the high temperature which attains its maximum southeast of the cyclone centre, and causes a high pressure in the upper air.

Another point of interest shown by the preceding results is that a cyclone cannot be looked upon as an eddy in a current like an eddy in a river, because the highest currents are moving five times as fast as the lowest, and the eddy would be rapidly destroyed. The cyclonic circulation is rather to be considered as continuously renewing itself and struggling against velocities of drift varying with the altitude.

RECENT FOREIGN STUDIES OF THUNDERSTORMS: III. FRANCE.*

R. DE C. WARD.

THE systematic study of thunderstorms in France was begun in 1865†, and has been continued since that time with the assistance of the Minister of Public Instruction, the Departmental Commissions, the Administration of Forests, and a large number of volunteer observers. The results derived from these data were at first edited by the Imperial Observatory at Paris, and published by the minister of public instruction, being issued as large folios, with prefaces by Le Verrier. From 1866 to 1876 they were published under the title *Atlas météorologique de l'Observatoire imperial*, the later volumes bearing the name *Ob-*

* For the previous papers of this series see this Journal, Vol. IX., 532-541; Vol. X., 111-126.

† This Journal, Vol. II., 1885-86, 489-492.

servatoire de Paris in place of *Observatoire imperial.* Since the establishment of the *Bureau central météorologique* in 1878, the results, beginning with the storms of 1876, have been published under the title of *Etudes des Orages en France* in the large quarto volumes of the *Annales du Bureau central météorologique de France.* The work has, since the beginning, been under the charge of M Fron, and the results of the investigation are regularly published by him at the beginning of each volume of the *Annales.* The last volume, recently issued, is that for the year 1890.

These summaries are a few pages long, and give a running account of the occurrence of the storms, their severity, the damage, if any; the number of departments from which reports were received, and a general description of the pressure and weather changes throughout the year. There is very little theoretical generalization, and nothing as to the nature, origin, and mechanism of thunderstorms. In connection with the summaries, and of greater value, are the fine charts which accompany these reports. The charts are on a small scale, but are sufficiently distinct for easy use. They are drawn for every day throughout the year on which thunderstorms were reported, and represent the storms by isochronal lines, for hours or half-hours. They also show the places where damage was done by lightning or hail; the direction of movement of the storms, and further, give the direction of the wind as noted at 7 A. M., in Brittany, and over the parts of the Channel, the Atlantic, and the Mediterranean adjacent to the shores of France. The study of these charts presents a most attractive subject for investigation, and such points as the geographic distribution of the thunderstorms of France, their places of origin, the effect of topography on their movements, etc., could well be worked up with this material at hand.

Besides the general summary and the smaller charts, there are special descriptions and charts, on a much larger scale, of particularly interesting storms that occurred during each year. In connection with each of these large scale charts there is a set of smaller ones which show the distribution of pressure over the district at three-hour intervals during the day.

From a brief survey of these charts and of the summaries, it appears that winter thunderstorms in France are few, scattered

and local; they come in warm southerly or southwesterly winds, and during the passage of a cyclonic depression over Great Britain, occurring in the right half of the depression. They seldom last more than two or three hours, and often not as long as that. Summer thunderstorms in France come in connection with cyclonic storms crossing Great Britain, the Channel, France, the North Sea, and Scandinavia, or with secondaries over France. The normal conditions for summer thunderstorms are uniform pressure over the district, weak gradients, calm atmosphere, and high temperatures. Many of the storms come from the ocean, and run ashore in southwestern France. The storms as shown on the charts as a rule cross only a part of the country; extended storms reaching from the Mediterranean to the Channel are rare. The isochronal lines often show a concave front. The general direction of movement is to the northeast, east, or southeast, but thunderstorms have been noted moving from east to west, and other directions are not uncommon. The wind arrows drawn on the smaller charts show quite distinctly that on thunderstorm days there is usually a cyclonic circulation of the winds around France, while on days with few or no reports of thunderstorms the circulation is generally anticyclonic. The three-hourly charts of pressure and winds would be very useful in working out the connection between the distribution of pressure and the development of thunderstorms, but they would be of more value if they included a more extended area than France alone. They would then make clear the relation of the pressure changes over France with the changes over Great Britain. As they stand, however, the development of secondaries and the occurrence of thunderstorms in connection with them are often clearly shown.

Besides the summaries by Fron there are occasional contributions concerning thunderstorms by other writers in the *Annales*. In the volume for 1885, M. Plumandon, of the Puy de Dome Observatory, has an article entitled "*Sur la Propagation des Orages.*" The writer divides thunderstorms into two classes,— those which occur in a more or less marked depression and those which develop where the atmospheric pressure is even. They usually come from some point between west and south or even southeast, and are part of a large storm extending to many other places. Sometimes, however, when the horizon is clear,

the zenith becomes cloudy and a "zenithal" thunderstorm is developed. The cloud mass remains stationary for a time, all the while increasing, when suddenly the storm commences and the clouds move away, the sky perhaps becoming clear again. The explanation of this phenomenon is given as follows: these local "zenithal" clouds are caused by a local ascending current of air. They form first in the lower calm air, and therefore remain stationary, but as the warm air in which they develop rises higher, it reaches the upper currents, which are moving, and when it does so the clouds are carried away. On Sept. 21, 1881, a number of photographs were taken, at the Puy de Dome Observatory, of an isolated cloud mass which began to form at 9.50 A. M., and did not move away until 11.40 A. M., at which time it began to rain and thunder.

Other cases occur in which a thunderstorm moves away from the place where it formed, although the higher clouds appear stationary and there seems to be no current of air to carry them, or in which the thunderstorm travels in a different direction from that of the prevailing wind. This is explained, the writer says, when we consider a thunderstorm as essentially similar to a cyclone, which has been generally supposed to have a motive power of its own due to the liberation of latent heat by the condensation of vapor, the cyclonic centre moving towards the region of maximum condensation. Large thunderstorms may be regarded as made up of smaller storms, which may move in many different directions, whatever the main line of progression. Thus it may happen that parts of the main storm may move by leaps towards a region of maximum condensation, such a region becoming the point of radiation of other storms.

Ferrari, whose work in connection with the thunderstorms of Italy is well-known, has summarized the thunderstorms of France from 1865 to 1877, taking as his material the charts published by Fron (*Ciel et Terre*, Vol. II. 1886, 350). It appears from Ferrari's work that thunderstorms from the west and southwest are the most frequent and travel with the greatest velocity. The following table shows the average velocity, in kilometers, of the storms coming from the different points of the compass: —

N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.
34	32	49	50	31	26	27	31

The majority of storms occur in the southeastern octant of cyclonic depressions.

In the volumes of the *Annuaire de la Société météorologique de France*, published under the direction of M. Léon Teisserenc de Bort, there are occasional short notes on local thunderstorms which, however, present no facts of general interest. In the *Annuaire* for 1885, Vol. XXXIII., 77–79, there is a summary of the thunderstorms in the Department de l'Allier, by M. Doumet-Adanson. The storms of this district are of two distinct kinds, local and general. The former begin on an undulating plateau between the Cher and Allier Rivers; are generally moderate, and often precede a larger storm, or are parts detached from a larger storm, which they follow after an hour or two. The general storms are due to the larger atmospheric movements, and cross the country as a band. Most of these larger storms come to the district from further west, and pass in an easterly or in a northeasterly direction. These are often destructive. The hourly distribution of thunderstorms is as follows: —

12 P. M.–6 A. M.	9 per cent.
6 A. M.–12 M.	12 per cent.
12 M.–6 P. M.	59 per cent.
6 P M.–12 P. M.	20 per cent.

Most of the storms moved less than sixty kilometers an hour; some, however, attained a velocity of sixty to one hundred kilometers. Hail usually accompanied the most rapidly-moving thunderstorms.

An interesting and timely article entitled "*Marche Apparente et Trajectoire Vraie des Orages sur l'Horizon*," by C. Millot, is found in Vol. XXXVIII., of the *Annuaire*, for 1890. The article is written for the purpose of instructing the thunderstorm observers how to record the direction of movement of thunderstorms, that being by no means an easy task. The writer mentions the fact that observers in France, — and we may add in New England also, — frequently note that the storm divided or turned around their places of observation. These statements are due to ignorance as to the true movement. A thundercloud appears on the horizon, and for some time seems to rise no higher, although it extends laterally. This appearance is due to the curvature of the earth's surface; and to the corresponding curvature possessed by the thunder-clouds.

While the lateral growth is going on in the distance, the forerunning cirro-stratus cover has already reached the observer's zenith. As this cloud-covering over the observer often seems very light as compared with the black and forbidding clouds which soon pass by him to the north and south, he feels that the storm has divided at his station, and he makes a note to that effect on his record, adding that the storm was heavy to the north and south. This belief is due to the fact that when the observer looks up at the clouds overhead he is looking through them at their thinnest point, whereas, when he looks north or south, he is in a line with the storm, and so his vision is through a much thicker mass of clouds, which consequently appear much blacker than they do overhead.

Further, another illusion comes in in relation to the movement of what seems to be two storms. When the storm is first seen on the horizon it appears one homogeneous mass. As it gradually approaches the observer it seems to divide, as just described, and after passing him seems to unite again, the whole effect appearing to show quite clearly that the thunderstorms have turned in a more or less complete semicircle around him. This idea of the dividing of the storm gains further support from the apparent separation of the clouds as they approach the zenith, due to their movement across the sky, not as a uniform mass, but in parallel lines, or rather, on the arcs of great circles converging at the horizon. It is readily seen that these great semicircles will be further apart as they approach the zenith, and the law of perspective will make the clouds appear nearer together and consequently more numerous, the nearer the eyes look to the horizon. It is the same effect as that produced when we look down between two long rows of trees or telegraph poles, the rows seeming to join in the distance. Therefore, as the storm nears the zenith, the clouds will diverge more or less overhead, while as the observer looks to either side of him, the rows of clouds overlap and it seems to him that the storm is much more severe on all sides of him, and he has been left in the middle of two showers, each of which makes a semicircle around his place of observation. As the storm moves on, he sees the whole process in reverse order, and before the disturbance disappears he notes the apparent joining of the supposed two storms on the eastern horizon. Even an isolated storm, passing at a dis-

tance, frequently seems, for the reasons already stated, to turn around an observer in a semicircle.

With regard to the points of appearance and disappearance of thunderstorms as related to the true trajectory of the latter, the following method of determination of the true course is given: suppose yourself looking down on a circle representing the limit of your horizon; yourself at the centre, and the points of the compass marked on the circumference. If a storm rises in the southwest, travels along the western horizon, and disappears in the northwest, what course has it followed? A line should be drawn from the southwest to the northwest points of the circle, representing the path of the storm. This line is parallel to the south-north diameter of the circle, and therefore the storm moved from south to north. If a storm rises in the southwest, passes behind you, supposing that you are facing north, and disappears in the east, what is its direction of movement? By joining the southwest and east points of your circumference, you have a line parallel to a west-southwest—east-northeast diameter of that circle, so that the direction of the storm's movement may be set down as west-southwest—east-northeast. This scheme furnishes a rule which may be stated as follows: the direction followed by a thunderstorm is that of the diameter of a circle drawn parallel to the line which joins the points of appearance and disappearance of the disturbance. This line is the true trajectory.

It will be seen from this brief review of recent studies of thunderstorms in France that the general characteristics of this class of disturbances are about the same in all the countries whose thunderstorms we have thus far studied. The amount of material at hand from France is not large, and we have noted the most important contributions to the subject since 1885.

Harvard College, July 1, 1893.

BALANCING OF THE CLOUDS.

E. A. LUSTER.

THE theories of hollow vesicles, ascensional currents, electricity, and friction having all failed to afford a satisfactory solution of cloud balancing, the following theory is suggested for examination: —

The specific gravity of water being so much greater than that of air, solid globules of water must of necessity sink to the ground unless supported by some power in opposition to gravity. It may be that this power is the well-known force of adhesion between air and water.

Since adhesion acts mainly on the surface, while gravity acts on the volume, or mass; and since the proportion of surface units to volume units increases rapidly as the volume diminishes, it follows that the force of adhesion increases inversely as the volume.

From formulæ of geometry we find this ratio to be $6 \div D$, when D is the diameter of the globule.

If the sustaining force of adhesion constantly multiplies as the volume decreases, there must necessarily be some approach to a minimum in size of globule where these two opposing forces, gravity and adhesion, will just balance at the average height of clouds. The smaller the globules the higher the clouds will float, and *vice versa.*

The adhesive force of water is evidently greater than the cohesive force. Now, this cohesive force can be approximately calculated by means of a drop of water clinging to a solid. It has an assignable value, and, therefore, *a fortiori*, has the force of adhesion.

There are many reasons for thinking the adhesive force between air and water is greater than the cohesive force of water alone. The raising of waves on the sea by the wind, and the failure to raise them when the surface of the sea is covered with oil, may be cited as an instance.

The adhesive force between the air and globules of water having an assignable value, it therefore follows that as the

globule diminishes, its weight will approach, in value, the uplifting power of adhesion.

If, as some meteorologists claim, clouds slowly but constantly settle downward, then the law of friction is a factor in the question. But if, as others assert and as seems to be the fact, clouds often remain stationary, or even rise, then friction is no necessary factor, for there can be no friction where there is no motion. Much less could friction obtain as a factor in rising clouds, unless these clouds are lifted up by ascending currents.

Much more could be adduced in support of the above theory, but possibly enough has been said to place it properly for examination by those interested in such things.

Fincastle, Va., June 17, 1893.

CURRENT NOTES.

The Climate of North Carolina. — A "General Sketch of the Climate of North Carolina" has been issued by the North Carolina Agricultural Experiment Station. From it the following quotation on the Types of Weather in that State is taken: —

"Notwithstanding the extreme irregularity of weather changes, certain relative arrangements of high and low areas often reoccur which produce each time the same kind of weather. The study of the types of weather for North Carolina has not been carried far enough to permit of more than a general description of the most prominent typical formations. With each of the cyclonic paths is associated a distinct sequence of phenomena. The relative positions of both high and low areas must be considered at the same time.

"First Type. The passage of a low area over the lake region with pressures above the normal in the vicinity of the Gulf or south Atlantic is the commonest type, occurring most frequently during summer. The wind blows from the south for a longer or shorter period with rising temperatures; it shifts to southwest with increasing velocity, with probably also increasing cloudiness, and if the trough of low pressure extending southward from the centre of the storm is sufficiently developed, rain may occur with a shift of wind to the northwest. In this case, the rainfall soon ceases, is never heavy, and is followed by a cooling of the atmosphere, which in winter may amount to a moderate cold wave. In summer the passage of the trough over the State produces the conditions favorable for thunderstorms, in which way most of the rainfall for the summer season occurs. This type is modified by the more northward or southward trend of the low. In the former case the shift of the wind to northwest may occur without cloud formation or rain. Under such conditions long periods of fair weather prevail, associated both summer and winter with temperatures much above the normal and slight wind movements. In autumn our Indian summers are caused in this manner. In the latter case, the southward trend of low, the ordinary phenomena of the type are more marked, and if the pressure falls low enough, severe thunderstorms with hail occur.

"Second Type. The weather associated with the passage of a low area from the region west of the Mississippi, northeast over the Ohio valley, is similar to that just described, if the high pressure remains in its former location. The presence of an area of high barometer over New England, however, offering some resistance to the normal course of the storm while the pressure is below the normal on the south Atlantic coast, causes many modifications of the phenomena usually observed. The influence of the mountains in this case has been noted. The frequent result of such an arrangement of pressure is continued cold northeast winds with drizzling rain, produced by the cold heavy air of the anticyclone underflowing the

warm moist air which would under ordinary circumstances be brought up by the low area. The occurrence of this type may be looked for in early spring, and once in July almost every year; the spell lasts from three to five days.

"Third Type. The weather phenomena caused by the passage of a cyclone from the Gulf to Florida and up the Atlantic coast are most interesting and important, as generally producing the most marked and rapid changes and the heaviest rainfall in this State. While the storm is still far distant in the west Gulf it sends forward warning of its approach in the shape of fine filaments of cirrus clouds, which drift over the sky from the west and southwest, soon changing into cirro-stratus which obscure the sun; the wind shifts to south or southeast with rising temperature; as the storm passes across Alabama and Georgia the cloudiness increases and general rains prevail over the entire State. If the storm passes over the western portion of the State the winds in the east shift back to south and then to southwest, the clouds break and after a few violent gusts of rain the storm is over, the wind finally shifting to west or northwest with falling temperature. If the storm passes up the coast the winds shift to northeast with increasing violence, continued rain, and, in winter, snow. The opposition of an area of high pressure over New England may cause a continuance of the 'northeast type' of weather for several days. In winter the presence of a cyclone following this path is frequently coincident with the appearance of a high area of considerable extent in Manitoba and Montana, causing steep barometric gradients in the rear of the storm, with brisk or high cold northwest winds, constituting a cold wave.

"The storms of this class, and those originating in the West Indies, cause the violent gales of the Atlantic coast which are so destructive to shipping in the great tracks of commerce. The approach of the hurricane from the West Indies is often unheralded by any of the usual signs. The best indication is the general shift of the wind to the northeast on the South Atlantic coast, and the movement of high cirrus or cirro-stratus clouds from the south or southeast, which is, however, very rare. The sequence of weather is then rapidly increasing cloudiness, rain or snow, violent northeast gales, suddenly shifting to west or northwest, with falling temperature and finally clearing weather. True tropical cyclones are most frequent in August and September.

"In regard to the weather in North Carolina, the most general and valuable rule deduced during observations of the past few years is this: any arrangement of high and low areas which will cause a drift of air from the land to the sea, that is west to east, will bring fine weather; any indrift from the ocean will produce increasing cloudiness and rain. If such an indrift lasts several days without the formation of rain, ultimately a period of rainy weather of several days' duration may be expected. Hence, the dry winds are from the southwest to north; the wet winds from northeast to south. The condition most favorable for heavy rain is the presence of a low area in Alabama or Georgia; the most favorable condition for dry weather is the persistence of a high area in the same position."

THOMAS G. HODGKINS.

THOMAS G. HODGKINS, whose name is associated with many generous gifts in behalf of science and philanthropy, was born in England in 1803. He came to America in 1830, and established himself as a manufacturer in New York City, where he amassed a considerable fortune. In 1859 he retired from active business and went to Europe, where he travelled and resided for many years. Returning to this country, he lived thereafter on his farm near Setauket, Long Island. Here he devoted his time to reading and study, thus acquiring an extensive fund of information, and becoming especially interested in certain branches of science, and particularly in the study of the atmosphere in its relationships to the highest welfare of man.

The success of Mr. Hodgkins in his business ventures proves him to have been a man of unusual penetration and judgment in such matters, and the use he made of the wealth he had accumulated betokens his broad philanthropy and his earnest desire to benefit his fellow-men. For many years it was his custom to give to the poor all the products of his farm, excepting the small portion required for his own use, and pursuing the same habit of systematic benevolence, he reserved from his large fortune but a comparatively insignificant sum for his own support, and himself personally superintended the distribution of his wealth for the advancement of the various philanthropic and scientific objects in which he was especially interested.

Mr. Hodgkins established a free library in the town of Setauket, the home of his later years. He gave largely to the American Society for the Prevention of Cruelty to Children, and to the American Society for the Prevention of Cruelty to Animals. He gave also $100,000 to the Royal Institute of Great Britain, and $200,000 to the Smithsonian Institution, to be incorporated with the general fund of the Establishment, but with the condition that the income from one half of this sum should be devoted, in accordance with the wishes of the donor, to the increase and diffusion of more exact knowledge in regard to the nature and properties of the atmosphere in connection with the welfare of man.

The Smithsonian Institution has accordingly announced three prizes from this fund, which will be awarded on or after July 1, 1894, should satisfactory papers on the topics designated be submitted.

1. A prize of $10,000 for a treatise embodying some new and important discovery in regard to the nature or properties of atmospheric air, in their bearing upon any or all of the sciences.

2. A prize of $2,000 for the most satisfactory essay upon the known properties of atmospheric air, considered in their relationship to any department of natural science, or upon the proper direction of future research in connection with the imperfections of our knowledge of the atmosphere.

3. A prize of $1,000 for the best popular treatise upon the atmosphere, its properties and relationships.

The original will of Mr. Hodgkins bequeathed all his property, not otherwise disposed of at the time of his death, to the United States Government,

but a codocil makes the Smithsonian Institution, and not the General Government, his residuary legatee.

Mr. Hodgkins died at his home in Setauket, Long Island, on the 25th of November, 1892, leaving to the world a legacy, not only through the generosity of his bequests, but by the impulse of his wise and benevolent design to further study and research in regard to subjects intimately connected with the daily life and welfare of mankind.

Pennsylvania State Weather Service. — The Pennsylvania State Weather Service, under the direction of the Committee on Meteorology of the Franklin Institute and of Mr. H. L. Ball, the Observer in Charge, has recently issued a series of charts in connection with its work, which are of more than usual interest. They are designed to answer two purposes: first, to show the result of the labors of the small body of men who, between 1837 and 1842, formed the first regular organization in America for systematic meteorological observations under State appropriations, and secondly, to exhibit the work of the Pennsylvania State Weather Service in existence at the present time.

In 1837, on the joint representation of the American Philosophical Society and the Franklin Institute, the State Legislature made an appropriation of two thousand dollars for the organization and conduct of a system of meteorological observations. Stations were at once established, and observers were obtained in other parts of the United States. These observers sent records to the two societies for a number of years, especially of the details of storms, whose nature and origin were at that time the subject of much controversy. "In spite of the disadvantages which the absence of facilities for the rapid transmission of news by railroad and telegraph imposed on these observers, the committee was furnished by its correspondents with the particulars of fourteen great storms, and was enabled, from the observed data, to evolve a practical theory of storms which is essentially the same as that now accepted as correct. The results obtained were tabulated, and for a number of years were published in the 'Journal of the Franklin Institute.' This early work, in which the State of Pennsylvania conspicuously distinguished herself, must be regarded as the first step towards the elaborate system which, to-day, with the aid of the telegraph, finds its expression in the Weather Services of this and other countries, and which has been of incalculable benefit to commerce and agriculture."

The present State Weather Service was organized in 1887, the bill presented to the Legislature having been drafted by a committee of the Franklin Institute. Since that time the Service has developed rapidly. A monthly bulletin has been issued since the beginning, and during the summer months a weekly crop bulletin is published. In addition, special publications have been issued from time to time.

The present charts give the results of the observers' work at each station since its establishment. The periods of observation vary greatly, although the larger number of stations have been in continuous operation since 1887. There are forty stations, with an average of twenty-two years of records, at which observations of temperature and rainfall have been made. Isothermal

lines at one degree intervals are drawn from data at stations at which observations have been made for periods of from ten to forty years. The charts are on a large scale, and show (1) mean temperature, mean precipitation, and prevailing direction of the wind for each month, based on the records for 1887–1892; (2) mean temperature and precipitation for each month at stations at which records were kept from 1837 to 1842; (3) mean annual isotherms; (4) mean annual precipitation; (5) precipitation from May 31 to June 3, 1889, which was the time of the famous Johnstown Flood; (6) the distribution of display stations.

The whole series of charts is a credit to the Pennsylvania Weather Service, and presents much valuable material for study. The distribution of precipitation as affected by the mountains, and the distribution of temperature over different parts of the singularly complicated surface of Pennsylvania could be well worked out in a careful study of these charts.

Sunshine Values at Ben Nevis Observatory. — Mr. R. C. Mossman has recently published an interesting article entitled *Sunshine Values at Ben Nevis Observatory*. This observatory is the highest station in Great Britain, its height above sea level being 4,407 feet. The sunshine recorder in use on Ben Nevis, since 1884, is the Campbell-Stokes instrument. A comparison of the values obtained on the summit during nine years, with those obtained at forty-six other stations, at approximately sea-level altitude, during ten years, shows that Ben Nevis had the least sunshine of any station during March to October inclusive. The sunniest part of the year on the Ben is the spring, this fact being due to the prevalence at that time of dry easterly winds. June has the most sunshine, the amount being twenty-six per cent of the possible. July has only fourteen per cent of the possible sunshine, and August only eleven per cent. The low percentage of the latter month is evidently caused by the increase of cloudiness due to the westerly winds which prevail then. August, 1889, and January, 1890, were the dullest months ever experienced on Ben Nevis, only two per cent of the total possible sunshine being then recorded. June, 1888, was the sunniest month, with forty-seven per cent of the possible.

The tables of the hourly sunshine values for the eight years ending January, 1892, show that the sunniest part of the day was from 11 A. M. to noon. During the late spring and early summer the maximum sunshine occurs in the forenoon, after which the amount diminishes till late in the afternoon, when there is a second maximum. This diminution about noon is evidently due to ascending air currents, which, rising from the surrounding glens, carry warm and moist air up towards the summit of the mountain where it is condensed into cloud. In this connection it is interesting to note that the low percentage of possible sunshine on Ben Nevis in May is probably due to the fact that during that month there is still a considerable quantity of snow on the upper slopes of the hill, this snow serving to aid in the condensation of the vapor in the ascending currents.

From an examination of the tables giving the number of sunless and sunny days for eight years, and the percentage of sunless and sunny days, some interesting facts are brought out. About seventy per cent of the days

had less than ten per cent of the total possible sunshine. During the eight years on fifty-two days more than ninety per cent of the possible sunshine was recorded; the highest percentage occurred on Dec. 30, 1887, when ninety-eight per cent was noted.

A comparison of the Ben Nevis results, and those obtained during the few months at the base station, Fort Williams, shows that the high level station received one third less sunshine than the low level, and the number of sunless days at the top was double that at the base. In February, November, and December, 1891, the summit station had more sunshine than the base.

The Squall of February 1, 1892, *in Great Britain.*— Mr. R. C. Mossman has recently written an account of a squall which crossed Great Britain on Feb. 1, 1892, and which presented a number of features of interest. In common with most of the winter squalls previously studied in that country, as well as in other parts of Europe and in New England, the disturbance was associated with the passage of an ill-defined V-shaped depression, lying, in this case, off the northwestern coast of Scotland. The 8 A. M. weather map showed a deep depression northwest of the Hebrides, and a bulging of the isobars southwards over the Irish Sea and south of England, the trough of the V being fairly well defined as far as the north of England. This trough was over five hundred miles long, and was associated with a series of squalls which occurred simultaneously along it. The disturbances were apparently due to a cold, westerly current impinging on a warmer one from the south, the conditions being similar to those under which tornadoes occur in the United States.

The general characteristics of the squalls were a rapid fall of the barometer preceding their arrival; and a heavy shower of hail, accompanied by a sudden shift of wind, amounting in some cases to eight points. With the hail the barometer rose again, temporarily, and the temperature fell several degrees. Rain continued to fall in most places for some time after the squall had passed. The squalls moved directly across Ireland, Scotland, and England in an easterly direction, the time occupied being twelve hours. The rate at which the V travelled was about forty miles an hour. Thunderstorms occurred at several places.

An interesting comparison of the observations at the Ben Nevis Observatory and at Fort William, the base station, shows that during the squall the barometer rose .04 in. at both places, but continued to rise for twenty minutes at the base after the barometer at the summit had begun to fall. The fall of the barometer which preceded the squall was much greater below than above, and the gradient at sea level much steeper than at the summit. The temperature also fell more quickly below than above. The direction of the winds at the summit shows that they blew straight from the area of lowest pressure, as shown by the sea level isobars, and in the teeth of them. This indicates that the gradients both for wind direction and velocity at the level of Ben Nevis were quite unexplained by means of the isobars drawn at sea level.

The Ben Nevis Station has already given meteorology some valuable

results, and in the present interest that attaches to data from high level stations a comparison, such as that just referred to, between the base and the summit observations, is particularly timely.

Recent Indian Meteorological Publications. — Among the recent publications of the Meteorological Department of the Government of India are the "Annual Summary" for 1891 and Part II. of Volume V. of the *Indian Meteorological Memoirs*, published under the direction of Mr. John Eliot, the present efficient head of the Indian Weather Service. The "Annual Summary" presents the results for the year in a compact form. Among the tables of special interest are those giving descriptions of the cyclones which affected the Indian area during the southwest monsoon period (May to September), with a tabulation of the greatest observed barometric depression; the character of the storms, and an account of their movements, velocity, etc. It is worthy of note that one of the longest-lived storms on record in India occurred between Sept. 19 and Oct. 3. It probably originated in the Gulf of Siam, crossed the Bay of Bengal, and finally filled up in the Northwestern Provinces on Oct. 3, after an existence of a fortnight. The storm gave very heavy rain to the districts through which it passed. The Summary is accompanied by eight plates, showing the tracks of the more important cyclonic storms; the mean distribution of pressure at 10 A. M. and 4 P. M. in January, April, May, and June, and the variation of the rainfall of all the months from the normal.

Under the title *Indian Meteorological Memoirs*, the Indian meteorologists have already given us many interesting and valuable histories of severe storms, or accounts of the rainfall, wind velocity, or other meteorological features of different districts. Volume V. deals with the Diurnal Variation of Atmospheric Conditions in India, being a Discussion of the Hourly Observations recorded at twenty-five Stations since 1873. Part II., which has just come to hand, contains the Discussion of Hourly Observations made at Patna and Hazaribagh. Patna and Hazaribagh are both in the northeastern part of India, Patna being on the southern bank of the Ganges, and representing the climatic conditions of the great Gangetic plain, and Hazaribagh being on the highest part of the plateau between the Gangetic delta and the Sone valley. The observations include pressure, solar radiation, nocturnal radiation, temperature, wind, humidity, and cloudiness. Twelve plates accompany the report, showing the diurnal variation of the various weather elements at the two stations under consideration.

Studies of the Australian " Burster."—The distinguished meteorologist, Hon. Ralph Abercromby, has given to the Royal Society of New South Wales the sum of £100 which is to be offered as prizes with the object of bringing about exhaustive studies of certain features of Australian weather. So far only one feature has been selected, and a prize is now offered of £25 for an exhaustive study of the well-known "Southerly Burster." It is understood that no essay which does not deal fully with the following points will be considered.

1st. The motions of the various strata of clouds for some hours preceding the time of and following the "burster."

2d. The weather conditions which lead up to and follow the "burster," with weather charts of Australia for the day of and day following it.

3d. The general conditions which modify the character of the "burster."

4th. The area of the "burster" and its track.

5th. Barograph traces showing the changes of pressure during the "burster."

6th. The direction and character of wind preceding it.

7th. The relation of "bursters" to rainfall.

8th. The essay must not exceed fifty pages of foolscap.

9th. The essay must be sent in not later than March 31, 1894.

10th. A photograph of each "burster" described, giving a characteristic view of the cloud-roll, should, if possible, be sent with the essay.

The essay must embody studies of several "bursters" and must be chiefly the result of original research of the author, but authors are not debarred from availing themselves of any available information, published or otherwise, on the subject.

A Remarkable Rainfall.—In *Nature* for May 4, Mr. Clement L. Wragge, late of Ben Nevis Observatory and at present Government Meteorologist of Queensland, notes a rainfall of 35.714 inches on Feb. 3, 1893, at Crohamhurst, in southeastern Queensland. Crohamhurst is on the western slope of Mont Blanc, a peak on a spur of the D'Aguilar Range of mountains, which are an offset from the Blackall Ranges. This remarkable rainfall was measured by a trained observer, so that implicit confidence may be placed in the figures. The gauge was a standard of the "eight inch" pattern, one foot above the ground, at an altitude of fourteen hundred feet above mean sea level. The gauge was emptied every three hours night and day during this great fall.

The greatest rainfall ever recorded fell at Chirapunji, in India, on June 14, 1876, when 40.8 inches were measured as having fallen in twenty-four hours. This gives an average of about 1.7 inches in an hour. Chirapunji has the largest annual rainfall in the world, the average being 493.2 inches. This excessive rainfall is largely due to the situation of the station on the side of a steep mountain four thousand feet in height, lying in the path of the moist southwest monsoon winds. These winds, coming from the sea, are constrained to rise over the mountain, and in so doing the air becomes cooled and the enormous precipitation there noted is the result.

Distribution of Hail in Wurtemberg from 1828 *to* 1890.—In the April number of the *Meteorologische Zeitschrift* there is a review of a recent work by Dr. Carl Robert Heck on the distribution of hail in Wurtemberg, based on the records kept from 1828 to 1890, and designed to serve as a basis for a State hail insurance. Among the interesting points brought out in this

report are the following: there seems to be no increase of hail with increase of altitude; the windward and leeward sides of isolated mountains have equal amounts of hail; the windward side of such long mountain ranges as are not parallel with the prevailing winds have more hail than the leeward side; hail-storms seem to follow river valleys, and forests apparently neither prevent the formation of hail-storms, detain them when once started, divert them, nor render them less violent.

The Cause of Earth Currents. — In *Nature*, for May 18, 1893, there is a note regarding the cause of earth currents which is of interest to meteorologists. In a paper recently read before the Institute of Electrical Engineers in London, Mr. O. E. Walker gave an account of his observations on earth currents in India, the result of which seems to show a close connection between the variations of earth currents and those of atmospheric pressure. The observations were made on four lines, and show that in the morning the current flows from the inland place of observation to the coast, while in the afternoon the direction is reversed. Further, the maximum current in one direction occurs at 10 A. M., at the time of the morning maximum reading of the barometer, and the maximum current in the opposite direction occurs at 3 P. M., the time of the afternoon minimum of the barometer.

CORRESPONDENCE.

THE DEFLECTIVE EFFECT OF THE EARTH'S ROTATION.

Editor of the American Meteorological Journal:

In contributing this note under the same title as that of Dr. Veeder's note in the JOURNAL for May, I have no wish to enter into a discussion of the subject, or to urge Dr. Veeder to believe in the deflective effect of the earth's rotation because other persons believe in it. My intention is simply to present a brief statement of the grounds for a belief that seems well founded to practically all students of meteorology.

1. There is a sufficient demonstration on mathematical grounds of the existence of a deflective force arising from the earth's rotation. This is regarded as convincing and logical by all who have followed it. Its demonstration is accessible in text books and special articles. The quantitative value of the force, for bodies moving on a level earth, without acceleration or resistance, is determined as precisely as is that of the centrifugal force arising from the earth's rotation. I do not understand that this mathematical discussion is called in question by anyone; nor should it be until its methods are shown to be faulty.

It may be worth while in this connection to call attention to a matter of terminology. Newton's first law of motion, — A body will forever remain at rest or forever move in a straight line at a constant velocity, unless acted

on by some force, — involves the definitions of force and inertia as follows: force is that which changes or tends to change the direction or velocity of a body's motion: and inertia is the resistance which a body opposes to a change in the velocity or direction of its motion. There is no special name for the manifestation of inertia that results from a change in the velocity of motion; but the inertia manifested when a body changes its direction of motion has a special name, — "centrifugal force." It is plain that the word "force" used in this name has not the same meaning as is given above in the definition of the ordinary term force. "Centrifugal force" is, therefore, essentially a misnomer; it must be taken not as meaning what it says, but simply as a name for the inertia-resistance manifested by a body when its direction of motion is changed.

The "deflective force" arising from the earth's rotation is in the same sense a misnomer. It is not a force in the true sense of that word; it is simply the name for the inertia-resistance that is manifested when a body is turned from the path that it would follow on a level, frictionless earth. This is all an old story, but it is worth occasional repetition.

2. A body moving without friction on the level surface of a planet would follow a curved path, continually deflected from a great circle. The radius of curvature of such an inertia path is determined; it varies with the rate of the planet's rotation, with the latitude, and with the relative velocity of the moving body, but not with the size of the planet. This is an immediate corollary of the previous statements, and is not questioned, as far as I have read.

3. In applying these principles to the case of the winds, we have not the simple problem of a body moving on a level earth without acceleration from external force and without friction. The winds move in virtue of continual gravitative accelerations on the barometric gradients; hence they are not free to follow the inertia curves appropriate to their velocity and their latitude; they are constrained to take a course intermediate between that of the accelerating force and that of the inertia curve. The attitude of this intermediate course depends in part on the friction that the wind encounters, and hence is not susceptible of close calculation; but the course as determined by observation accords so satisfactorily with the expectations of theory that the theory may be safely accepted as established. It may be added that the proper understanding of the problem of the winds does not lead to the expectation that tropical cyclones should whirl slowly, on account of the small value of the deflective force in low latitudes; hence I do not find in this matter the discrepancy that Dr. Veeder mentions. A close study of Ferrel's "Popular Treatise on the Winds" will make this clear.

4. The facts of observation that accord with the expectations of theory are: the oblique courses of the trade winds and of the circumpolar westerly winds, and with these, the correlated facts of low pressures around the poles and high pressures around the meteorological tropics; the change in the course of the trade wind as it crosses the equator, forming a monsoon, and apparently causing the equatorial counter current of the oceans; the normal veering of the sea breeze, the unvarying direction of cyclones in either hemi-

sphere, and the absence of tropical cyclones from the immediate neighborhood of the equator. No other sufficient cause for all these facts has ever been suggested. Even if there were not independent mathematical grounds for believing that the rotation of the earth would produce these special features in the course of the winds, we should be warranted in expecting such a control simply from the symmetrical grouping of the facts with respect to the equator. Indeed, it seems to me no more reasonable to say, " We know the earth rotates from west to east, becauses the sun rises and sets," than to say, " We know the earth rotates from west to east because the winds of the temperate zones blow prevailingly from the west around the relatively low pressures about the poles, because of the pole-east and Q-west * courses of the monsoons, because of the regular turning of cyclones to the left in this hemisphere, and to the right in the other." The mere rising and setting of the sun does not demonstrate the rotation of the earth, until we add a knowedge of the sun's distance and size and an understanding of the laws of motion. The ancients were long contented with another explanation of the sun's rising and setting, and said nothing about the earth's rotation. Long after the days of the ancients, so little was known about the winds, that no one quoted their blowing in evidence of the earth's turning. But as a knowledge of the laws of motion gradually accumulated to reasonable fulness, sunrise and sunset were taken as proof that the earth turned around; and with the present knowledge of the facts of meteorology, we need no longer explain the oblique courses of the winds as a result of the earth's rotation; we may logically employ those well attested facts as demonstrating that the earth really does rotate, just as sunrise and sunset had led us to expect. If the facts of temperature, pressure, and winds were presented to a competent mathematician, he would necessarily conclude that the earth turns, even if he knew nothing of astronomy.

5. Recalling some of Dr. Veeder's earlier articles, I think his skepticism goes further than throwing doubt on the deflective effect of the earth's rotation. He has, if I remember correctly, at one time or another expressed hesitation in accepting the convectional theory of the general circulation of the atmosphere. The evidence in favor of this theory is generally regarded as conclusive. The theory is rationally based on the demonstrated principles of physics and mechanics. The expectations of the theory are most beautifully borne out by the facts. The correspondence of deduction and observation is so precise that it is impossible to find room for doubt between them. Indeed it is difficult to understand how anyone, to whom the facts of meteorology and the principles of physics are familiar, can withhold belief in so well-founded a theory as that of the convectional circulation of the atmosphere. Belief in such a case does not seem to be a matter of preference or intention; the evidence is as compulsory to the mind as gravitation is to the body. The mind is held to belief, as the body is held to the earth.

*These are terms that I often use in teaching so as to avoid terms like *northeast* and *southwest*, which apply only to one hemisphere.

As I said in the beginning, these paragraphs are not offered as arguments but rather as statements of the reasons of belief. The argument is so sufficiently presented in other places that it is not needed here.

W. M. Davis.

LIGHTNING AND RAIN-DROPS.

Editor of the American Meteorological Journal: —

Witnessing recently the laboratory experiment illustrating the magnetic field which surrounds every electric current and noting how the iron filings became magnified and clustered together, it suggested to me a possible solution of the phenomena of heavy rain-drops that follow the overhead lightning flash in our thunderstorms. Presuming that some, at least, of the dust particles in the air are mineral, these would become magnets when brought within the magnetic field created by the lightning. These tiny magnets would be drawn together in clusters, thus reducing the number and increasing the size of the dust particles. The fewer dust particles in the air, the fewer and larger will be the size of the rain-drops. It is scarcely necessary to add that these observations are based on Prof. Aitken's "Dust Theory" of the formation of rain-drops. H. R. Hilton.

Topeka, Kan., May 29, 1893.

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REYNMANN'S WETTERBUECHLEIN.

L. Reynmann. *Wetterbuechlein, von wahrer Erkenntniss des Wetters.* 1510. Facsimiledruck mit einer Einleitung. Neudrucke von Schriften und Karten ueber Meteorologie und Erdmagnetismus. Herausgegeben von Prof. Dr. G. Hellmann, No. 1. Berlin, A. Asher & Co., 1893. 4to, pp. 42, 14.

Under the title of *Neudrucke von Schriften und Karten ueber Meteorologie und Erdmagnetismus*, Dr. Hellmann, the well-known German meteorologist, has recently begun the publication of a series of pamphlets which will undoubtedly be of great value and interest to meteorologists all over the world, as well as to literary persons who are in any way interested in old books. Dr. Hellmann's plan is to reprint various old and rare writings on meteorology and terrestrial magnetism, which were of importance in the development of these sciences, or which have great historical value. Facsimiles are to be published in cases where the writings are particularly rare or are typographically noteworthy, and every issue will have an introduction containing a bibliographical account of the reprint, as well as other facts of interest in connection with it. It is a great satisfaction to note that, owing to the financial assistance rendered by the German Meteorological

Society, and by its Berlin branch, the price of these reprints will be relatively low, so that they may be widely circulated.

The first issue of the series is a fac-simile reproduction, with an introduction, of L. Reynmann's "*Wetterbuechlein, von wahrer Erkenntniss des Wetters*," originally published in 1510. It is in quarto form, with rough white paper covers, and is in all respects a most attractive book. The introduction gives us an abundant store of facts concerning the original. The Wetterbuechlein is the oldest meteorological work published in German, and although it went through seventeen editions in thirty-four years, numbering probably at least eighty-five hundred copies, there are hardly three dozen copies of it to be found at the present time. In view of these facts Dr. Hellmann decided to publish a fac-simile of it.

The Wetterbuechlein is, as its title implies, a simple introduction to the true understanding of the weather, or, as we should say now, to forecasting the weather from simple signs. It contains in its fourteen chapters a large number of natural weather signs and rules, which can be found in the ancient classical literature, but it gives much more space to natural signs, such as optical phenomena and clouds, than to astrological appearances.

In preparing his bibliography Dr. Hellmann corresponded with one hundred and fifteen libraries throughout Germany, Austria, and Switzerland, and he has given a most concise account of the various editions. The first edition, published in 1505, is entirely lost, not a single copy of the book as first issued having been found. The fac-simile is taken from the second edition of 1510. The book was not only generally read in Germany, but it even found its way to England, and appeared in almost literal translation in *The Boke of Knowledge of Thynges Vnknown, apperteyning to Astronomy, with certain necessarye Rules*, published in London in 1585.

As to the sources from which Reynmann drew in preparing his work, Dr. Hellmann believes they were principally two,—one a large astrological treatise published in 1491 by Guido Bonatti, an Italian astrologer of the thirteenth century, and the other a work entitled "*Opusculum repertorii pronosticon in mutationas æris*," by a Frenchman named Firminus, published in 1485. Concerning the author of the Wetterbuechlein, practically nothing can be found out, beyond the fact that he lived in Nuremberg about the year 1520, and was an earnest astrologer. He wrote a few other things.

The fac-simile occupies the last fourteen pages of Dr. Hellmann's publication, and is certainly most interesting reading. It treats of the forecasts which may be based on halos, clouds, rainbows, thunder and lightning, hail, etc., and we hope at some future time to reprint a few of the more noteworthy weather proverbs therein contained. We heartily commend this book to all readers of this JOURNAL, especially to those who are interested in the subject of weather proverbs. It is published by A. Asher & Co., of Berlin, at the low price of six marks ($1.50), and can, we presume, also be procured through Dr. Hellmann himself.

PASCAL'S RECIT DE LA GRANDE EXPERIENCE DE L'EQUILIBRE DES LIQUEURS.

Blaise Pascal. *Récit de la Grande Expérience de l'Equilibre des Liqueurs.* Paris, 1648. Facsimiledruck mit einer Einleitung. Neudrucke von Schriften und Karten ueber Meteorologie und Erdmagnetismus. Herausgegeben von Dr. G. Hellmann, No. 2, Berlin, A. Asher & Co., 1893, 4to, pp. 10, 20.

The second issue in Dr. Hellmann's new series of reprints brings before us the fac-simile of a very rare work indeed, as there are at present only three copies of the original in existence,— two in Paris and one in Breslau. The original was printed in Paris in 1648. The fac-simile occupies twenty pages of the present pamphlet, and is clear and distinct. As Dr. Hellmann says, this little publication was of the very highest importance for the history of physics, meteorology, and physical geography, for it gave conclusive proof of the existence of atmospheric pressure and put an end to the doctrine of *horror vacui.*

The price of this second number of the series is three marks (75 cents). We are glad to note that Dr. Hellmann proposes to issue a reprint of Luke Howard's *On the Modifications of Clouds*, originally published in 1803, which was the first attempt at cloud classification. The cloud forms are to be reproduced in fac-simile. Dr. Hellmann may be assured of the hearty appreciation and the thanks of American meteorologists in his labor in issuing these most valuable and interesting reprints.

THE RAINFALL TYPES OF THE UNITED STATES.

A. W. Greely. *Rainfall Types of the United States.* The National Geographic Magazine. Vol. V., 1893, pp. 45–58, pl. 20. 8vo. Washington, 1893.

In this paper Gen. Greely presents a classification of the rainfall of the United States in types, based on the characteristic distribution of precipitation throughout the year. The types are of two kinds, simple and composite, the latter occurring where two simple types gradually shade or merge into each other. The simple types can be expressed by a curve with a single bend or inflection; the composite would be shown by two inflections, from a primary maximum through the minimum to a secondary maximum and secondary minimum.

The simple types are as follows: Pacific, Mexican, Missouri, Tennessee, Atlantic, and St. Lawrence; and in general it may be said that each of these simple types appertains to a single body of water for its resulting precipitation. The Missouri type, however, has two sources, the Gulf of Mexico and the Great Lakes and Hudson Bay.

The Pacific type is the best defined type of rainfall; it covers British Columbia, Washington, Idaho, Oregon, California, Nevada, and western

Utah, and is characterized by very heavy precipitation during midwinter and an almost total absence of rain during the late summer.

The Mexican type dominates western Texas, New Mexico, and the greater part of Mexico, and is characterized by very heavy precipitation after the summer solstice, and a very dry period after the vernal equinox. Arizona has a composite rainfall, resulting from the interference of the Pacific and Mexican types, and Colorado and the eastern part of Texas have a rainfall resulting from the interference of the Mexican and Missouri types.

The Missouri type of rainfall is the most important in the United States, both from the vast area which it covers and from its favorable bearing on agriculture. It dominates the water sheds of the Arkansas, Missouri, and upper Mississippi rivers, and of Lakes Ontario and Michigan, covering Montana, the Dakotas, Minnesota, Nebraska, Kansas, Iowa, Missouri, Oklahoma, Wisconsin, and Illinois, with parts of Arkansas. Texas, Michigan, Indiana, and Indian Territory. Its characteristics are a very light winter precipitation and the occurrence of the greater part of the yearly precipitation in late spring and early summer.

The Tennessee type occurs in Tennessee, Arkansas, Mississippi, eastern Kentucky, western Georgia, and Alabama, and Louisiana, except on the immediate Gulf Coast of the two last-named States. Its heaviest rainfall comes in the last of the winter or at the beginning of spring, with the minimum in mid-autumn.

The Atlantic type characterizes the whole of the Atlantic coast except New England, the distribution of rainfall being nearly uniform throughout the year. In New England the Atlantic type is possibly interfered with by the St. Lawrence type. It has an August maximum followed by a second maximum in November, a June minimum and a second minimum in September or April.

The St. Lawrence type dominates the St. Lawrence valley. It has a heavy rainfall in the late summer and autumn months, with a maximum in November and nearly as heavy rain in July or August, and a scarcity in the spring months.

In concluding his paper Gen. Greely says: "There is no doubt in my mind that the maxima and minima phases of precipitation are simply the result of the fluctuation throughout the year of atmospheric pressure over North America and its contiguous waters, thus affecting the relative positions of high and low areas and consequently causing winds, either favorable or unfavorable to precipitation, according to season and locality."

Gen. Greely's paper presents a classification which seems to us a simple and rational one. The whole question of rainfall and of its classification is one of the most interesting subjects in meteorology, and the beautiful test of the general theory of the winds which is offered in a rainfall chart of the world, is one of the most striking examples of the correlation of the various meteorological elements. So, in the present classification of the rainfall of the United States, so intimately associated with the movement north and south of the tropical belts of high pressure and of the changes in pressure with the seasons, we find additional facts of correlation between winds and rainfall in the seasonal changes of the two elements.

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